CLAIMS

What is claimed is:

1. A method of determining the location of a medical probe, comprising:

wirelessly transmitting first and second signals between a location element mounted on the medical probe and first and second reference elements;

determining a transit time difference between the first and second signals;

determining a distance difference between a first distance extending from the location element to the first reference element and a second distance extending from the location element to the second reference element, based on the transit time difference; and

determining coordinates of the location element within a coordinate system based on the distance difference.

2. The method of claim 1, wherein the first and second signals are acoustic signals.

3. The method of claim 1, wherein the first and second signals are simultaneously transmitted.

4. The method of claim 1, further comprising receiving the first and second signals, and determining times that the amplitudes of the received first and second signals cross an amplitude threshold, wherein the transit time difference is a function of the threshold crossing times.

5. The method of claim 4, wherein the first and second signals are simultaneously transmitted, and the function is a difference function.

6. The method of claim 1, further comprising receiving the first and second signals, and cross-correlating the received first and second signals to obtain a time shift between

the received first and second signals, wherein the transit time difference is a function of the time shift.

7. The method of claim 6, wherein the first and second signals are simultaneously transmitted, and the function is an identity function.

8. The method of claim 1, wherein the first and second reference elements are arranged in an array, the method further comprising determining an angle between an imaginary line intersecting the location element and the array and a first imaginary plane intersecting the imaginary line, wherein the angle determination is based on the distance difference and a predetermined distance between the first and second reference elements, and the coordinate determination is based on the angle.

9. The method of claim 8, wherein the coordinate determination is further based on the length of the imaginary line.

10. The method of claim 8, wherein the imaginary plane is perpendicular to another imaginary line extending between the first and second reference elements.

11. The method of claim 8, wherein the imaginary line bisects another imaginary line extending between the first and second reference elements.

12. The method of claim 1, wherein the first and second reference elements are located exterior to a patient's body when the first and second signals are transmitted.

13. The method of claim 1, wherein the coordinate system is a two-dimensional coordinate system.

14. The method of claim 1, further comprising:

wirelessly transmitting a third signal between the location element and a third reference element;

determining another transit time difference between the first and third signals;

determining another distance difference between the first distance and a third distance extending from the location element to the third reference element based on the other transit time difference; and

determining coordinates of the location element within a coordinate system based further on the other distance difference.

15. The method of claim 14, wherein the coordinate system is a three-dimensional coordinate system.

16. A medical system, comprising:

a medical probe;

a location element mounted on the medical probe;

first and second reference elements; and

a registration subsystem configured for wirelessly transmitting first and second signals between the location element and the first and second reference elements, determining a transit time difference of the first and second signals between the location element and the respective first and second reference elements, determining a distance difference between a first distance extending from the location element to the first reference element and a second distance extending from the location element to the second reference element, based on the transit time difference; and determining coordinates of the location element within a coordinate system based on the distance difference.

17. The system of claim 16, wherein the location element and first and second reference elements comprise acoustic transducers.

18. The system of claim 16, wherein the registration subsystem is configured for simultaneously transmitting the first and second signals.

19. The system of claim 16, wherein the registration subsystem is configured for receiving the first and second signals, and determining times that the amplitudes of the received first and second signals cross an amplitude threshold, wherein the transit time difference is a function of the threshold crossing times.

20. The system of claim 19, wherein the registration subsystem is configured for simultaneously transmitting the first and second signals, and the function is a difference function.

21. The system of claim 16, wherein the registration subsystem is configured for receiving the first and second signals, and cross-correlating the received first and second signals to obtain a time shift between the received first and second signals, wherein the transit time difference is a function of the time shift.

22. The system of claim 21, wherein the registration subsystem is configured for simultaneously transmitting the first and second signals, and the function is an identity function.

23. The system of claim 16, further comprising a rigid structure on which the first and second reference element are arranged in an array, wherein the registration subsystem is configured for determining an angle between an imaginary line intersecting the location element and the array and a first imaginary plane intersecting the imaginary line, wherein the angle determination is based on the distance difference and a predetermined distance between the first and second reference elements, and the coordinate determination is based on the angle.

24. The system of claim 23, wherein the coordinate determination is further based on the length of the imaginary line.

25. The system of claim 23, wherein the imaginary plane is perpendicular to another imaginary line extending between the first and second reference elements.

26. The system of claim 23, wherein the imaginary line bisects another imaginary line extending between the first and second reference elements.

27. The system of claim 16, wherein the coordinate system is a two-dimensional coordinate system.

28. The system of claim 16, wherein the rigid structure is a patch configured to be located on the skin of a patient.

29. The system of claim 16, further comprising a third reference element, wherein the registration subsystem is further configured for wirelessly transmitting a third signal between the location element and the third reference element, determining another transit time difference of the first and third signals between the location element and the respective first and third reference elements, determining another distance difference between the first distance and a third distance extending from the location element to the third reference element based on the other transit time difference, and determining coordinates of the location element within a coordinate system based further on the other distance difference.

30. The system of claim 29, wherein the coordinate system is a three-dimensional coordinate system.

31. The system of claim 16, wherein the medical probe is a catheter.

32. The system of claim 16, wherein the medical probe is an ablation catheter.

33. The system of claim 16, wherein the medical probe is an electrophysiology mapping catheter.

34. A method of determining the location of a medical probe using an array of reference elements, comprising:

wirelessly transmitting first and second signals between a location element mounted on the medical probe and first and second reference elements located within the reference array;

determining a transit time difference between the first and second signals;

determining a distance difference between a first distance extending from the location element to the first reference element and a second distance extending from the location element to the second reference element, based on the transit time difference;

determining an angle formed by the location element and the reference array based on the distance difference and a distance between the first and second reference elements; and

determining coordinates of the location element within a coordinate system based on the angle.

35. The method of claim 34, wherein the first and second signals are acoustic signals.

36. The method of claim 34, wherein the first and second signals are simultaneously transmitted.

37. The method of claim 34, wherein the coordinate system is a two-dimensional coordinate system.

38. The method of claim 34, wherein the coordinates of the location element are determined based further on a distance between the location element and the reference array.

39. The method of claim 34, wherein the first and second reference elements are located exterior to a patient's body when the first and second signals are transmitted.

40. The method of claim 34, further comprising:

wirelessly transmitting a third signal between the location element and a third reference element located within the reference array;

determining another transit time difference between the first and third signals;

determining another distance difference between the first distance and a third distance extending from the location element to the third reference element based on the other transit time difference;

determining another angle formed by the location element and the reference array based on the distance difference and a distance between the first and third reference elements; and

determining coordinates of the location element within the coordinate system further based on the other angle.

41. The method of claim 40, wherein the coordinate system is a three-dimensional coordinate system.

42. A medical system, comprising:

a medical probe;

a location element mounted on the medical probe;

a reference array having a rigid structure and first and second reference elements mounted on the rigid structure; and

a registration subsystem configured for wirelessly transmitting first and second signals between the location element and the first and second reference elements, determining a transit time difference between the first and second signals, determining a distance difference between a first distance extending from the location element to the first reference element and a second distance extending from the location element to the second reference element, based on the transit time difference, determining an angle formed by the location element and the reference array based on the distance difference and a distance between the first and second reference elements, and determining coordinates of the location element within a coordinate system based on the angle.

43. The system of claim 42, wherein the location element and first and second reference elements comprise acoustic transducers.

44. The system of claim 42, wherein the registration subsystem is configured for simultaneously transmitting the first and second signals.

45. The system of claim 42, wherein the coordinate system is a two-dimensional coordinate system.

46. The system of claim 42, wherein the rigid structure is a patch configured to be located on the skin of a patient..

47. The system of claim 42, wherein the registration subsystem is configured to determine the coordinates of the location element based further on a distance between the location element and the reference array.

48. The system of claim 42, wherein the reference array has a third reference element mounted on the rigid structure, and wherein the registration subsystem is further configured for wirelessly transmitting a third signal between the location element and the third reference element, determining another transit time difference between the first and third signals, determining another distance difference between the first distance and a third distance extending from the location element to the third reference element based on the other transit time difference, determining another angle formed by the location element and the reference array based on the distance difference and a distance between the first and third reference elements,

and determining coordinates of the location element within the coordinate system further based on the other angle.

49. The system of claim 48, wherein the coordinate system is a three-dimensional coordinate system.

50. The system of claim 42, wherein the medical probe is a catheter.

51. The system of claim 42, wherein the medical probe is an ablation catheter.

52. The system of claim 42, wherein the medical probe is an electrophysiology mapping catheter.

53. A method of determining a transit time difference between first and second signals, comprising:

wirelessly transmitting the first and second signals between a location element mounted on a medical probe and respective first and second reference elements;

receiving the first and second signals;

cross-correlating the received first and second signals to obtain a signal time shift between the received first and second signals; and

determining the transit time difference as a function of the signal time shift.

54. The method of claim 53, wherein the first and second signals are acoustic signals.

55. The method of claim 53, wherein the first and second signals are simultaneously transmitted.

56. The method of claim 55, wherein the function is an identity function.

57. The method of claim 53, wherein the first and second signals are cross-correlated by:

incrementally time shifting the first and second signals relative to each other;

multiplying the first and second signals for each time shift;

generating a plurality of values as a function of the signal multiplications over time;

identifying a maximum value from the plurality of values, wherein the signal time shift is the time shift corresponding to the maximum value.

58. The method of claim 57, wherein the function is an integration function.

59. A medical system, comprising:

a medical probe;

a location element mounted on the medical probe;

first and second reference elements; and

processing circuitry configured for wirelessly transmitting first and second signals between the location element and the respective first and second reference elements, receiving the first and second signals, cross-correlating the received first and second signals to obtain a signal time shift between the received first and second signals, and determining a transit time difference between the first and second signals as a function of the signal time shift.

60. The system of claim 59, wherein the location element and first and second reference elements comprise acoustic transducers.

61. The system of claim 59, wherein the registration subsystem is configured for simultaneously transmitting the first and second signals.

62. The system of claim 59, wherein the function is an identity function.

63. The system of claim 59, wherein the processing circuitry cross-correlates the first and second signals by:

incrementally time shifting the first and second signals relative to each other;

multiplying the first and second signals for each time shift;

generating a plurality of values as a function of the signal multiplications over time;

identifying a maximum value from the plurality of values, wherein the signal time shift is the time shift corresponding to the maximum value.

64. The system of claim 63, wherein the function is an integration function.

65. The system of claim 59, wherein the medical probe is a catheter.

66. The system of claim 59, wherein the medical probe is an ablation catheter.

67. The system of claim 59, wherein the medical probe is an electrophysiology mapping catheter.